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ABSTRACT

An action research framework is used to learn what cooperative learning activities mean to students in a physical chemistry course, to discover how the activities can be improved, and to learn how students' perception of cooperative learning changes. Through an analysis of field notes and a student questionnaire, two findings emerged which describe students' perception of cooperative learning activities. Cooperative learning activities provide a mechanism for students to develop a feeling of community in the classroom and relationships are viewed as a positive force in learning that promotes achievement through commitment and mutual goals. Among students whose perception of cooperative learning changed from negative to positive, the key factor is the promotion of commitment and mutual goals among group members. Other related factors explored include student preparation for group work, the role of teacher as facilitator of student learning, and conceptual learning. It is concluded that fostering a climate in which cooperation is accepted and expected will lead to an environment in which a wider range of student learning styles is supported. Contains 52 references. (DDR)

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An Action Research Project on Student Perspectives of Cooperative Learning in Chemistry: Understanding the Efficacy of Small-Group Activities

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An action research framework was used to learn what cooperative learning activities meant to students in a physical chemistry course, to discover how the activities could be improved, and to learn how the students' perception of cooperative learning changed. Through an analysis of field notes and a student questionnaire two findings emerged which describe the students perception of cooperative learning activities. Both of these findings hinge upon student student interactions which promote the formation of relationships. First, we found that cooperative learning activities provided a mechanism for students to develop a feeling of community in the classroom. Through interacting with each other the students sensed that they could rely on each other and trust each other, thus a feeling of community grew. Second, relationships were viewed as a positive force in learning which promoted achievement through commitment and mutual goals. Students facilitated each other's learning by teaching each other, sharing approaches to problem solving, and asking questions. The students became committed to each other and helped each other learn the material. The most frequent recommendation for improving the activities focused on methods of maximizing student interactions during cooperative learning activities. Among students whose perception of cooperative learning changed from negative to positive, the key factor was the promotion of commitment and mutual goals among group members. Our findings allow us to gain a better understanding of how and why small group activities produce positive outcomes. In addition, they also relate to student preparation for group work, to the role of the teacher as a facilitator of student learning, and to conceptual learning.

National calls for reform in science, mathematics, engineering, and technology (SME&T) undergraduate education have urged faculty and institutions to shift their emphasis and focus from teaching to learning (NSF, 1996; NRC, 1996). The National Science Foundation (1996) recommends that SME&T faculty "recognize that different students may learn in different ways" (p. 65). Beyond introducing students to the processes of science, they also recommend that faculty "devise and use pedagogy that develops skills for communications, team work, critical thinking, and life-long learning" (p. 65). National advisory committees, researchers, and employers all point towards using cooperative, small-group activities as a method of enhancing achievement, attracting and retaining women students in SME&T majors, and developing "professional life skills" such as communication and team work skills (NSF, 1996; NRC, 1996; Cohen, 1994; Qin, Johnson, & Johnson, 1995; Tobias, Chubin, & Aylesworth, 1995; Seymour, 1995; Seymour & Hewitt, 1994).

These recommendations are aligned with the fact that each student has a preferential learning style. In order to attract and retain a more diverse population of students in SME&T courses faculty must acknowledge and act upon variations in student learning styles. This requires faculty to acknowledge that they have a preferred teaching style which interacts with a student's preferred learning style. Discrepancies between learning and teaching styles are a source of conflict, frustration, and discouragement among students and teachers (Grasha, 1996). Some of the clearest data which documents this incongruity appears in Sheila Tobias' They're Not Dumb, They're Different: Stalking the Second Tier (1990). The failure to acknowledge, to understand, and to accommodate for variations in teaching and learning styles often results in the faculty frustration. Rarely is there a recognition of the synergy between student's learning styles and faculty teaching styles, and even more infrequently is this knowledge acted upon (NSF, 1996; Grasha, 1996).

Using small-group activities is one way to acknowledge different student learning styles. Whether the groups solve problems, perform open-ended laboratories, give presentations, or prepare for quizzes or exams, discussing information in a group requires students to be more active

in their learning. These activities obligate faculty to do something other than lecture, which may involve modification of teaching practices--i.e. modification of teaching style. Moving from the expert authority figure in the classroom to a facilitator of student learning requires effort, resolve, and the courage to take risks. It is certainly easier to answer student questions than to encourage students to try a different approach, to consult a different source, or to explore other options. When acknowledgment of variations of student learning styles is accompanied by an awareness of different teaching styles, then altering classroom interactions between students and teachers may be more successful (Grasha, 1996).

Recent reviews of small-group activities have shown that cooperative learning leads to positive outcomes such as higher achievement, increased positive attitudes toward the subject area studied, higher self-esteem, greater acceptance of differences among peers, greater persistence and retention, and enhanced conceptual development across content areas and in a wide range of educational settings (Cohen, 1994; Qin, Johnson, & Johnson, 1995). Focusing on college students, Springer, Stanne, and Donovan (1997) conducted a meta-analysis on the effects of small-group learning in order to "facilitate a greater understanding of the effects of small-group learning at the postsecondary level (p. 3)." While Springer et al. (1997) lamented that many college and university SME&T faculty have not responded to the call to include opportunities for group activities, they found that numerous forms of small-group learning were effective in promoting achievement, cultivating positive attitudes towards learning, and increasing persistence and retention in SME&T programs.

These reviews, and most other studies on cooperative learning, have primarily used quantitative means to arrive at these conclusions. In order to understand the efficacy of small-group learning, (or cooperative learning), qualitative methods must be used to inform our understanding of how and why small-group learning promotes positive outcomes. We need to add the voices of the students to contextualize how and why cooperative learning produces higher achievement, greater persistence, retention, and other positive outcomes.

The goals of this study were to learn what cooperative learning activities meant to the students involved in them, to discover how the activities could be improved via student suggestions, and to learn how the students' perception of cooperative learning changed. Ultimately, this information will help us understand how and why cooperative learning promotes positive outcomes such as higher achievement, and increased persistence and retention. Thus, the following research questions guided the study:

1. What did the cooperative learning activities mean to the students involved?
2. What recommendations did students offer to improve or augment these activities?
3. How did the student's perspective of cooperative learning change after being involved in these activities?

Methodology

The character of qualitative research is dependent upon the credibility of the researchers (Patton, 1990). Thus, it is important to disclose the theoretical framework (or viewpoint) of the researchers because we brought our own biases, preconceptions, and experiences to this study. We decided what questions to ask, how to collect the data, and how to execute the data analysis. Our theoretical framework influenced the findings which evolved by providing a lens through which we viewed the research questions which guided this study, gathered and analyzed the data, and generated our findings. Consequently, a description of our theoretical framework, the researchers, the participants, the site, and the data collection and analysis procedures is necessary in order to understand the findings.

Theoretical Framework

To gather information which addressed our three research questions, we used an action research model (Kemmis & McTaggart, 1988; O'Hanlon, 1996; Zuber-Skerritt, 1996). This framework involves a sequence of planning, implementation, observation, and reflection, which emphasizes the link between classroom practices, the analysis of such practices, and their improvement. When carried out in the teacher's own classroom, this model can lead to changes in curriculum and/or

classroom practices through the development of new perspectives on student learning and teaching. Thus, reflecting on one's classroom practices leads to enlightenment on the part of the researcher and hopefully, positive changes within the researcher's classroom.

Because our primary data sources were written documents, we also used a theoretical approach associated with interpretation of ancient texts--hermaneutics. Within this tradition, educational researchers use qualitative methods to construct meaning based on written information--questionnaires, journals, quizzes, or exams for example--provided by the participants (Patton, 1990). In our study, each researcher brought her own classroom experiences as a student (and teacher) to the interpretation of the student questionnaire responses. This richness of experience allowed us to discuss different ways of analyzing, interpreting, and synthesizing the data.

The primary researcher (third author) approached this project with a strong belief in the constructivist theory of knowledge (Lincoln & Guba, 1985; Schwandt, 1994; von Glasersfeld, 1991). Her classroom experiences have lead her to believe that in order for students to engage in meaningful scientific learning as opposed to simply memorizing mountains of equations, derivations, and definitions, students must connect new knowledge to their existing knowledge in ways that make sense to them (Edmondson & Novak, 1993). Thus, her constructivist views drive her classroom practices and influence her selections for research endeavors (O'Hanlon, 1996; Zuber-Skerritt, 1996).

Description of the Researchers, the Participants, and the Site

The primary researcher carried out this research project in her own classroom. She has experience teaching chemistry in secondary and post-secondary settings. Cooperative learning methods have been a component of her classroom since the fall semester of 1994, and she has published articles and given presentations related to cooperative learning (Kreke & Towns, 1996; Towns, 1996; Towns, 1997a; Towns, 1997b; Towns , 1997c; Towns & Kreke, 1997a; Towns & Grant, 1997b) . Her research experience includes both qualitative and quantitative educational projects, and basic scientific research.

The first and second authors served as undergraduate research assistants for this project. Kreke has previous experience in performing and presenting qualitative research (Kreke & Towns, 1996; Towns & Kreke, 1997a; Towns, Kreke, Sauder, Stout, Long, & Zielinski, 1997). Both undergraduate researchers have a experiential understanding of constructivist learning, and Fields, as a preservice secondary chemistry teacher, has a strong interest in the use of teaching methods which engage students.

The participants were undergraduate students at a large midwestern university in the United States. The class was composed of 32 students--17 women and 15 men. Twenty-five of the students were science majors, and seven were preservice high school chemistry teachers. One student was a minority, and all of the students spoke English as a first language. One student dropped the course.

The course was an undergraduate level thermodynamics course tailored for chemistry majors. Students attended three lectures, one three-hour lab, and one "problem solving session" (PSS) each week. As the semester progressed, the lecture became oriented around 15-30 minute lecture segments and 5-10 minute small group activities. During the PSS, students solved conceptual or algorithmic problems in groups of four to six students which remained intact the entire semester. Once the problems were solved, groups presented their solutions to their peers, or the entire class engaged in a discussion.

Data Collection

We directed the data collection at capturing the students perceptions of cooperative learning activities. Field notes and the student's responses to a questionnaire provided data upon which we based conclusions regarding our guiding questions. The primary researcher recorded classroom observations and informal student-professor conversations outside of class as field notes in order to describe events which took place during cooperative learning activities. During the 14th week of the semester a questionnaire was administered to 30 out of 31 students. The questionnaire contained questions of a general nature about the course and questions which centered on PSS

(See Appendix). For example, we asked "What were your perceptions of the course?" as well as "What are the strengths of the PSS's?" By asking these questions the students were able to discuss their experiences in the course and during cooperative learning activities.

Data Analysis

We analyzed the questionnaire using an open coding scheme (Strauss & Corbin, 1990). First, we created a transcript that grouped data by question. Reading the transcript question by question each researcher looked for themes or patterns in the responses. For example, the students were asked to write about the strengths of the PSS's. Some of the students wrote that the PSS's gave them an opportunity to *teach/learn from each other* and *to build friendships.* These themes were given codes which were used to identify these themes within each student's response.

We met as a team to discuss the rationale behind our individual coding schemes and subsequently developed a joint coding scheme (Abell, Dillon, Hopkins, McInerney, & O'Brien, 1995). We then re-analyzed the data individually, and developed categories and properties which naturally emerged from the data. As a team we discussed our individual categories and their properties. Field notes were used to support or refute these emerging categories and properties. The product of our discussions were categories which helped us formulate our findings. By moving between the data, our research questions, and our individual perspectives we were able to triangulate our findings, enhancing the credibility of our study (Abell et al., 1995; Patton, 1990; Lincoln & Guba, 1985).

Findings Part I: Student Perspectives of Cooperative Learning

Two findings emerged which describe the students perception of cooperative learning activities. Both of these findings hinge upon student-student interactions which promote the formation of relationships. These relationships may be collegial in nature, classmates forming relationships in order to learn the material, or they may be friendships which extend beyond the classroom into other school related or social activities. Wherever these relationships lie on the colleague to friend continuum, they bring about important effects in the classroom. They promote a feeling of

community among the students and they promote the formation of mutual commitment and mutual goals among group members.

Finding #1

We found that cooperative learning activities provided a mechanism for students to develop a feeling of community in the classroom. Elyse's voice spoke for many students in the course:

> "PSS gave me an opportunity to meet other students and to work in a group. I usually work better in a group and I felt like I had a support system."

Through interacting with each other, students sensed that they could rely on each other and trust each other. For example, Martin wrote that one of the strengths of the PSS's was that "others would help you understand." This type of reliance, believing that group members were concerned about each others success in learning the material, was voiced by many students. This notion of "sinking or swimming together" is known as positive interdependence in the cooperative learning literature (Johnson, Johnson, & Smith, 1991). Mary exhibited a feeling of positive interdependence among the members of her group when she wrote:

> "The strengths of PSS are that if someone in the group doesn't understand the problem usually someone else will."

In this classroom, the impact of positive interdependence among group members was the development of a feeling of community within each group.

Finding #2

We found that collegial relationships were viewed as a positive force in learning which promoted achievement through mutual commitment and mutual goals. Students became committed to each other and helped each other learn the material. Erin's comments are typical of students who voiced this commitment:

> "It [PSS] taught me that there are lots of was to look at things and its worth it to listen to what other group members say. It is also very rewarding to be able to help someone who has helped you on something different."

Repeatedly, the students wrote about the reward of learning the material through "work(ing) together" and "explaining the problems I understood to others." The idea of mutual goals also appeared when the students described how their perception of cooperative learning had changed. In particular, some students emphasized that a group which developed mutual goals and became committed to each other was a productive and positive place to learn. As Jenny wrote: "Its nice to be in a class where most, if not all, actually care about know/learning this stuff well."

Students facilitated each other's learning by teaching each other, sharing translations or different approaches to solving problems, and asking each other questions. Linda wrote:

> "My group was fantastic in that we were able to work together and learn from each other. A lot of things that I learned from this course, I learned in PSS."

In order to engage in these activities students had to use effective interpersonal and communication skills. To "work together and learn from each other" as Linda wrote means that students had to listen to each other with respect, to ask critical questions, and to support and encourage each other's efforts. Students had to translate or relate their own understanding of concepts and problem solving techniques to other students in their group. For example, Kevin and Ken wrote about relating their understanding of the material to other group members. Clearly, both believed that this interaction helped them learn the material.

> "I am able to get a better grasp and more confident about the material when I teach it to my group." (Kevin)
>
> "[the strengths of PSS are] To learn quickly how to do the problems by watching and listening to others; and learning the material well as a results of explaining the problems I understood to others." (Ken)

As students discussed different approaches to problem solving they related their understanding (or translation), to other students. Tony believed that this exchange produced "a lot of opinions on how to do the problems" and was a strength of the group activities. Amazingly, Justin wrote that "it is sometimes better for someone other than the teacher to explain the material" raising the

possibility that another student may have a more accessible translation or approach than the instructor!

Students also wrote about the importance of being able to ask each other questions. Through these queries students assessed their own understanding, and contributed to a feeling of positive interdependence among group members. As Kristi wrote:

"Once you settle in a group, you feel comfortable asking questions and helping others (which also helps you learn)."

It is clear that building a feeling of community allowed students to form mutual commitments and goals which promoted learning the material through teaching each other, sharing approaches to problem solving, and asking each other questions.

One mutual goal that students mentioned was knowing how to approach examination and quiz questions. Dale wrote that PSS "helped me study since it gave me definite examples of what I must know how to do." By working in an active fashion to solve problems some students realized that they did not have a thorough understanding of the topics under study. Lou Anne's quote illustrates this progression from teaching each other in an active fashion to success on individual assessment.

"If one or two of us didn't understand something usually someone in PSS could explain in it. If not, we know we need to ask questions. This <u>really</u> helped when it came down to test time."

The formation of mutual commitments and goals, aided by positive relationships between students and the use of effective interpersonal and communication skills, facilitated learning and promoted achievement.

Findings Part II: Student Recommendations for Improvement of Cooperative Learning Activities

As part of this action research project, it is important to acknowledge the students as stakeholders who can generate recommendations which would improve practices. It is a method of honoring their voice, and when students are credited with authoring an improvement which is subsequently implemented, it empowers them to become more engaged in their learning. It is from this perspective on pedagogy and our research questions that we viewed the students responses.

One third of the students suggested methods of maximizing student interactions. Seven students simply wanted all of the activities to be assigned in class. Leila's comments illustrate the sentiments of this group:

"I think the problems should be done in PSS as a group. If the problems are given early then everyone goes an does them on their own."

This group of students did not favor assignments which required out of class work--longer problems, or problems requiring library research--because these out of class activities diminished the power of working in a group. In fact, only one student supported assigning problems which required preparation outside of class.

Three students mentioned the "jigsaw" structure as a favorite method of learning how to do a problem and teach it to their peers (Johnson, Johnson, & Smith, 1991). This structure involves the formation of transient groups composed of one member from each base group. The goal in the transient groups is for each person to become an expert at solving a particular problem. When this task is accomplished, group members return to their base group and explain how to solve their particular problem to their group mates. Lu Anne found the jigsaw structure to be a particularly effective method of learning the material--"I felt like I learned more when we worked problems as a group, then switched so that the new groups had a person to explain their problem, rather than explaining in front of the class."

Eight students recommended altering the group activities by either changing group composition more often during the semester, lengthening the time period in which the groups could interact, or performing group processing activities more frequently. Four students recommended relating the PSS questions more to the examination questions and to lecture. Finally, one fourth of the students did not recommended changes.

As part of honoring the students' voice, these recommendations were acknowledged the following semester via class discussion. Subsequently, some of the recommendations were implemented. Only one out of class assignment was given during the semester. Small group

activities were used more often during lecture, and the groups spent more time solving problems during PSS. The jigsaw procedure and group processing were used more frequently.

Findings Part III: Student Descriptions of How Their Perception of Group Work Changed

The student responses were coded into five categories; four that involved permuting prior perceptions (positive or negative) with end of the semester perceptions (positive or negative), and one category which included responses which were not easily classified as positive or negative. The most striking finding appeared within the group of students whose perception changed from negative to positive. Within this group, seven out of nine students perceived that there was no positive interdependence among group members in their previous small group experiences. This recurrent theme emerged in responses such as "no one worked together", "I'm the major contributor to most of the work", and "I did a lot of the work for another person". It was clear that none of these students enjoyed working in groups where piggy-backing or free-loading was allowed to occur. Linda's quotation is representative of this group of students.

> "When I first learned that we had to work in groups, I dreaded it because my experience of groups so far has been terrible because no one worked together. But my group changed my perception of group work. I believe that my group was the best group in the class. We became good friends too."

When cooperative learning is structured so that positive interdependence is not perceived, individual responsibility is not required/perceived in order to reach the group's goal, effective interpersonal skills are not taught/used, and group processing is absent, then group work is ineffective. When there is a balance between positive interdependence among group members and individual responsibility, coupled to mutual commitment, mutual goals, the use of effective interpersonal skills, and group processing, then group work can promote achievement.

Thirteen students had positive perceptions of group work both prior to participating in PSS and afterwards. As a group, these students agreed that "several heads working on a problem from several directions is better than one."

Two students had negative perceptions of group work prior to participating in PSS and afterwards. These students were not fond of group work, but felt that it would work sometimes, and that it was "good to know that I can do it if it is necessary." Based on the need for team work skills in industry (CPT, 1996; Tobias, Aylesworth, Chubin, 1995; AAAS, 1997), it appears that it is more than good for students to know how to work in groups since it will have a significant impact on their productivity.

One student provided an interesting negative example. Melanie, a preservice chemistry teacher, was the only student whose perception changed from positive to negative after being involved in PSS. She wrote:

> "This is the first time I ever was pretty much inactive in group work. I think I have a better understanding of the "quiet" ones who are unable or afraid to talk. I had always been a leader in group learning and here I was an observer."

Melanie had trouble with the material in the course, and considered dropping it. At the beginning of the semester she often arrived late for PSS, and since the group had already begun working on problems, she did not ask for clarification or help from other group members. Because of personal commitments outside of the course, she did not meet with her group to study for quizzes or examinations. During the last half of the semester she obtained a tutor and became more confident during lecture and when interacting with her group. She answered more questions during class, and participated more frequently in her group's discussions even though she continued to arrive late. Melanie's previous experiences in group work via her education courses had given her a positive perception of group work. However, in this course, her perception was that "[she] was pretty much inactive" even though this self assessment was not true for the last half of the semester. This experience had a positive spin however, she believed that in her future teaching that she would "have a better understanding of the quiet ones" who are reluctant to contribute to the group.

Melanie's case is interesting because it identifies the importance of effective communication skills and group processing. Without her groupmates deciding that "everyone needs to contribute"

she might have been completely left out of group interactions. Her own actions to improve her understanding and confidence, combined with the mutual commitment of the group to "everyone contributing" created an environment which allowed Melanie to become a more active member of the group. From the perspective of Melanie as a future teacher, she learned that the road to building an effective group is not without bumps, blind spots, and detours. It requires a mutual commitment and effort from all group members to build an effective group.

Implications

Our findings allow us to gain a better understanding of how and why small group activities produce positive outcomes such as higher achievement, increased persistence and retention. We believe that listening to student voices provides an important payoff for researchers and practitioners. These voices move us beyond the "black box" approach to small group activities because they provide information on the efficacy of small group learning activities.

Drawing on the multi-dimensional nature of the relationships between our findings, as illustrated in Figure 1, allows us to address the question of how and why small group activities promote achievement, and increase persistence and retention. Cooperative learning activities provide a mechanism for students to build a feeling of community in the classroom. Through interacting with each other and forming relationships, students learn to rely on each other and to trust each other, thus building a feeling of community. As they begin to rely on each other and trust one another they form mutual commitments and mutual goals. Students facilitate each others learning by using effective interpersonal skills and communication kills. They teach each other, share approaches to problem solving, and ask questions. Students try to understand different ways of explaining concepts and different approaches to solving problems. Since rewards are not limited, students believe that rewards such as good grades are attainable. The feeling of community fostered by mutual commitments and mutual goals produces high interdependence among group members, which in turn promotes achievement, persistence, and retention.

As we reflected on our study, we tried to develop a more holistic view of our findings and teaching and student learning. We felt compelled to cultivate this global view because one of the results of an action research project can be the alteration or transformation of teaching and student learning. Thus, in addition to addressing the question of efficacy of small group activities, we developed connections to preparing students to work in groups, to the teachers role in forming a feeling of community, and to conceptual learning. We also believe that our findings relate to learning styles, life-long learning, the loss of women from SME&T undergraduate majors, and professional preparation of science majors and preservice teachers.

Preparation of Students to Work in Groups

Our findings affirm the importance of preparing students to work in groups (Nurrenbern, 1995; Prégent, 1994; Towns & Grant, 1997). It is impossible for the students to build a feeling of community, to form mutual commitments and to develop mutual goals, unless they know each other's names and agree on a set of operating rules (Chen, 1997; Kreke & Towns, 1997).

Within cooperative learning the teacher is viewed as a facilitator of student learning, or as Alison King wrote a "guide on the side" (1993). The process of facilitating student learning begins by helping students learn how to work with each other. It is incumbent upon the facilitator (the faculty) to help groups proceed through the four stages in the life of a group--forming, storming, norming, and performing (Tuckman and Jensen, 1977; Manning, Curtis, & McMillen, 1996).

Team building exercises can help group members get to know one another (forming), and develop operating rules (Nurrenbern, 1994; Towns, 1996). As the group begins to solve problems together, struggles are inevitable as they learn to interact with each other and accomplish tasks. Reminding the group to use their operating rules and leading the group through a group processing discussion are two methods that faculty can use to help the group move through this storming stage. As the group proceeds into the norming stage a feeling of community and mutual commitment grows. Group members share mutual goals, and solve problems and accomplish tasks by sharing insights and different perspectives. Finally, the group reaches the performing

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stage where they use effective interpersonal and communication skills to nurture and maintain the group, and focus on solving problems and completing difficult tasks.

Conceptual Learning

Our findings indicate that cooperative learning can be an effective method of helping students learn concepts, thus narrowing the gap between algorithmic and conceptual understanding (Towns & Grant, 1997; Towns & Kreke, 1997b; Nakhleh, Mitchell, & Lowrey, 1996). Cooperative learning encourages interaction among students and active engagement in the material. When conceptual problems are the focus of group discussion, then students may be required to explain, elaborate, or justify their reasoning. This discourse not only encourages students to generate an understanding from more than one perspective, it also encourages students to evaluate and to integrate knowledge in new ways (Towns & Grant, 1997). Thus, cooperative learning activities can cultivate connections between concepts and lead to a more integrated and valid understanding of the material under study.

Assessment of conceptual learning in chemistry has become an active area of scholarship both in terms of research and test item development (Bowen & Bunce, 1997; Nakhleh, 1995; Patron, 1997; Patron & Bodner, 1997; Schwenz, 1997; Thomas, 1997; Thomas & Schwenz, 1997; Wandersee, Mintzes, & Novak, 1994). Bowen and Bunce (1997) provide guidance on writing conceptual questions which make use of recent research on student misconceptions. In addition, the American Chemical Society Examinations Institute has developed conceptual exams in general chemistry, and is currently developing a conceptual exam for physical chemistry (Eubanks, 1997; Schwenz, 1997).

Learning Styles

Each fall and spring semester faculty face students who each have a preferential mode of perceiving and processing information. These students each possess a preferential learning style. Figure 2 represents Kolb's description of learning styles which combines the way a person perceives information with how he or she processes it (Kolb, 1984; McCarthy, 1987). The y axis represents perception with the words concrete experience and abstract conceptualization at

opposing ends. Some people perceive or comprehend information through concrete experiences such as hearing, seeing, or touching. Others perceive information abstractly through symbols, equations, and concepts. Each student has a place where he or she is most comfortable on this concrete to abstract continuum. How people process information is represented by the words active experimentation and reflective observation. Some students prefer to process information actively and dive right in--discussing different approaches, setting up equipment, etc.--while others prefer a more watchful, reflective approach. Based on these continuums, Kolb identified four learning styles represented by the four quadrants in Figure 2.

Each of these learning styles can be characterized by a favorite question as shown in Figure 3: why is this important, what is the concept, how is it applied, and what are the possibilities. These questions model a learning cycle that begins with motivating students by connecting their previous experiences to the concepts under study. It then moves to providing information to students and time for reflection. The third quadrant is characterized by giving students the opportunity to apply concepts in situations such as laboratory experiments, or small group activities. Finally, the problem is changed slightly to include new possibilities.

Incorporating cooperative learning activities into Kolb's Learning Cycle permits students to answer questions which favor their preferential learning style while challenging them to examine, discuss, and experience content from a different learning style. Such activities coax students who are most comfortable in the what is the concept quadrant--where most scientists lie--into connecting concepts with previous experiences by asking why is this important, and extending their understanding of concepts by asking what are the possibilities. These more global and inductive questions can be addressed during group activities where the exchange of ideas and insights among group members may lead to a more integrated understanding of the material under study.

The National Science Foundation--in-step with other national reports, college and university mission statements, and faculty--expressed a desire to produce life-long learners in their recent report on undergraduate SME&T education (1996). Faculty can address this issue by teaching students to traverse the four quadrants of the Kolb Learning Cycle, thus providing a model that

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students can use to teach themselves (Harb, Durrant, & Terry, 1993). Students who can teach themselves will be better prepared to succeed in a global economy characterized by a diverse workforce, rapidly changing technology, and interdisciplinary approaches to problem solving. Science faculty must acknowledge that it is impossible to teach students everything that there is to know about a given subject area since we are constrained by time and resources. However, we can help students learn methods of teaching themselves, allowing them to become life-long learners and citizens capable of meaningfully "resolving issues involving scientific and technological content (Kyle, 1997)."

Loss of Women From SM&E Undergraduate Majors

Our findings relate to the ongoing discussion of the loss of women from science, mathematics, and engineering majors. As described by Elaine Seymour (1995), the notion of being "challenged" within the science curriculum creates a climate based on competition to prove oneself. Within this framework, a normative grading system serves to weed-out the unworthy (or defective), and heightens student anxiety by not allowing them to determine what is a good, average, or poor performance. This environment essentially kills cooperation among students. If rewards are limited, then helping other students to achieve is denying oneself a potential reward.

Our findings harmonize well with other cooperative learning studies which found that cooperative learning promotes achievement (Cohen, 1994; Qin, Johnson, & Johnson, 1995; Springer, Stanne, & Donovan, 1997). In practice, this hinges upon clearly stating a grading scale. To form mutual commitments and goals students need to know that the rewards, in terms of good grades, are not limited. Simply put, encouraging cooperation in a normed grading classroom is like trying to grow a garden on a concrete slab. Promoting a climate of competition via a normed grading scale will not allow cooperation to flourish.

Another interesting notion contained in Seymour's work is the idea of a "smartness rating" among peers. One method of preserving this rating is to have one's peers believe that you are inherently smart. Thus, doing well by "working hard" as some women said they did, counted for less than being inherently smart. Males sought to preserve their rating by not asking questions in

class, or by not working with others. Women who openly discussed their questions about the material, who sought to form study groups, and who asked questions in class, openly broke the rules of this status system. Thus, the mismatch between some students preferred learning style and the accepted teaching/learning style correspondence portends a loss of status for students who break the "rules."

Seymour's findings are striking when compared with the learning styles favored by women according to McCarthy (1987). Women are the majority of students who fall into quadrants I and IV, and men form the majority of students in quadrants II and III. Frequently used science teaching methods such as formal lecture, instructor lead problem solving and demonstrations, guided labs, and computer simulations match well with students whose predominant learning styles fall in quadrants II and III. Cast in this light, it is understandable that students who ask "why is this important", and "what are the possibilities" become frustrated and switch out of science majors. The teaching methods used are a poor match to their preferred learning styles.

Sheila Tobias' They're Not Dumb, They're Different: Stalking the Second Tier (1990), also shed light on why students leave SME&T majors. The participant observers used in the study were highly successful students (and one professor) in disciplines other than science. These students lamented the absence of community in introductory science courses, and the exclusive use of teaching methods which "did not play to my strengths (p. 62)." The mismatch between student learning styles and faculty teaching styles appeared over and over. Stephanie clearly describes the disappointment and frustration born of this lack of correspondence.

> "What was I supposed to be learning in chemistry? A way to look at the subject? Do the problems correctly? Become analytical? . . .In the humanities and social sciences we are taught to ask "why" questions. In chemistry I felt we were only being taught to ask "how." . . . If we didn't know "how' we surely couldn't pass the exams. [I felt that] those of use who prefer "why" questions do not survive in this course. It has no use for us, no patience with us, and we are pushed away. (p. 58)"

Because differences in student learning styles are not recognized nor acted upon in many introductory science courses, students like Stephanie become alienated in SME&T courses. Ultimately, this lack of acknowledgment leads to students to doubt that they can succeed in these majors. The students switch, and in a remarkable grasp of the obvious, faculty fret about attraction and retention.

The Workplace, Professional Preparation for Science Majors

The development of interpersonal skills and communication skills during cooperative learning activities is important to the student's future success in the workplace. For many students, the use of cooperative learning activities in a science course marks the first occasion that technical competence is balanced with interpersonal competence. During cooperative learning activities students develop the interpersonal skills and communication skills that impact their future employability and productivity (Johnson & Johnson, 1989b). "Professional skills" such as effective written and oral communications skills, the ability to understand the power structures, the ability to make decisions, and the ability to work in a team are cited by scientists working in industry as some of their most valuable career skills (Tobias, Chubin, and Aylesworth, 1995). Indeed the ability to work in a team, strong oral and written communication skills, and undergraduate research were cited by participants in the American Chemical Society Committee on Professional Training Industrial Round Table as the skills that industry looks for in new hires in addition to technical competence ("Cooperative Learning and Teamwork", 1996).

Preparation of Future Teachers

Our findings also relate to the preparation of future teachers. Better preparation of science teachers is called for in NSF Shaping the Future (1996):

> "Prospective teachers must be expected not only to learn SME&T content but also to come to appreciate that all students can learn and to approach their tasks as teachers from that perspective. They must also learn how to become effective facilitators of student learning in their teaching careers . . . Regardless of the specific structure and content of teacher preparation programs, improved undergraduate SME&T teaching generally is an essential precondition of

more effective teacher preparation. It seems likely that elementary and secondary teachers will tend to teach as they were taught as undergraduates. (p. 53)"

One method of acknowledging to teaching majors that different people learn in different ways is to use a variety of teaching methods in content area courses. For future teachers, these experiences may be the difference between simply hearing about alternative assessment, journaling, or small group activities in education courses, and actually observing how they work in a classroom. Such experiences may inspire preservice teachers to try similar activities in their own classrooms as Mike wrote:

"Group work is great. Do more. I plan to use some of the PSS group strategies in student teaching next semester."

By modeling effective facilatation of student learning in content area courses preservice teachers can see the importance of acting upon differences in student learning styles. Such experiences may also promote their professional development as facilitators of student learning.

Science faculty often have the opportunities to include undergraduate teaching assistants (TA) in their courses. In a study of beginning secondary science and mathematics teachers, Adams and Krockover (1997) found that students who had TA experiences believed that it eased the transition into their own classroom by preparing them to become a practicing teacher. As Adams and Krockover wrote:

"This [the TA experience] presents an unparalleled opportunity for preservice teachers to practice their pedagogical and content knowledge in an environment where discipline and management problems are of lesser concern . . . It seems apparent that the participants who had some exposure to teaching through the TA experience found it to be extremely beneficial because it allowed them to work on the teaching of content without the pressures and responsibilities of a public school teaching situation. Adequately supervised, the undergraduate TA experience provides a mechanism for preservice teachers to focus on student learning. (p. 46)"

Exposing preservice teachers to pedagogy which acknowledges differences in student learning styles via TA experiences may be a method of supporting their professional development as teachers. If it is true that "elementary and secondary teachers will tend to teach as they were taught as undergraduates" (NSF, p. 53), then it is vitally important that preservice teachers be involved in TA experiences or classroom experiences which expose them to pedagogy other than lecture.

Summary

Our action research framework has allowed us to develop an understanding of how and why cooperative learning produces positive outcomes such as higher achievement, and increased persistence and retention. By building community in the classroom through positive interdependence, mutual commitments, and mutual goals, students were able to promote each other's achievement and facilitate each other's learning by teaching each other, sharing different approaches to problem solving, and asking each other questions. These findings help move our understanding of the efficacy of small group activities beyond the "black box" perspective. Recognizing the importance of building community and mutual commitment and goals among group members corresponds in practice to acknowledging the significance of preparing students to work in groups and stating a grading scale. Fostering a climate in which cooperation is accepted and expected will lead to an environment in which a wider range of student learning styles are supported.

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Appendix

First Semester PSS/Course Survey

Circle one: Male Female Course - Circle one: 344 340

Now that you've been in the class one semester and had a chance to participate in some cooperative activities (PSS), I want you to reflect on those activities and the course. Think back over the Fall semester and answer the following questions.

1. As you look back over the semester, what are your perceptions of the course?
2. What were the strengths of the PSS's? How were they helpful to you?
3. What suggestions do you have for improving the PSS's?
4. Describe how your perception of group work has changed after being involved in PSS.
5. How should PSS be evaluated?
6. Please write any other comments that you have about the course.

Figure Captions

Figure 1: Kolb's Description of Learning and Learning Styles

Figure 2: Kolb's Description of Learning and Learning Styles

Figure 3: The Kolb Learning Cycle

FIGURES

Figure 1.

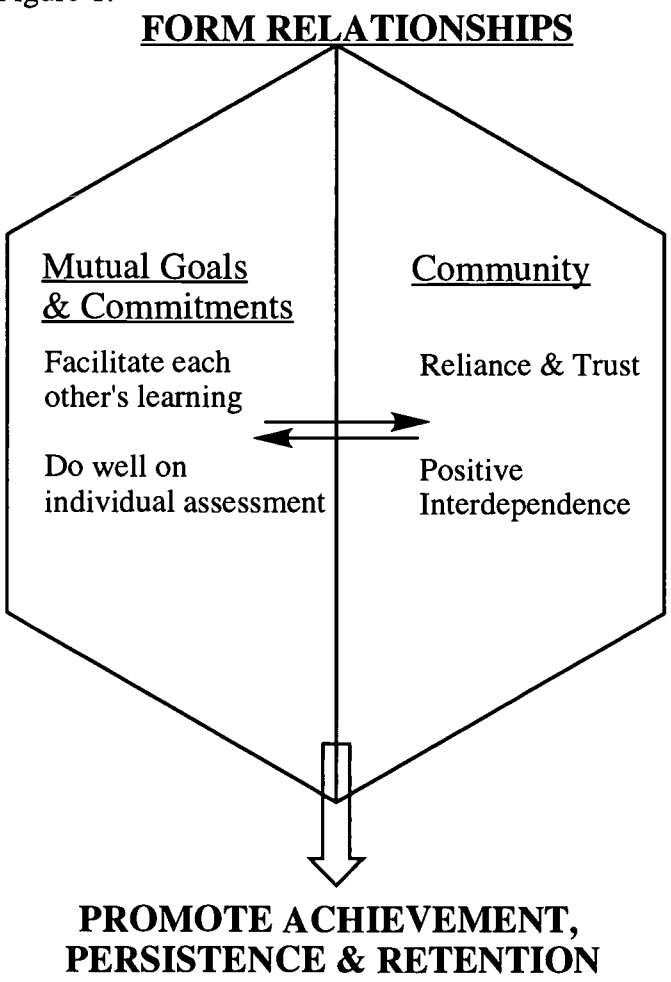


Figure 2.

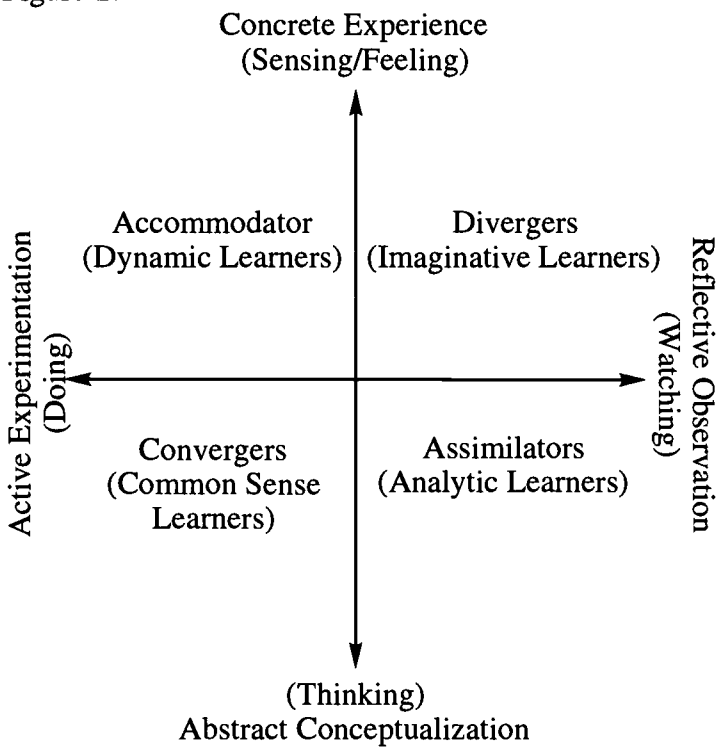
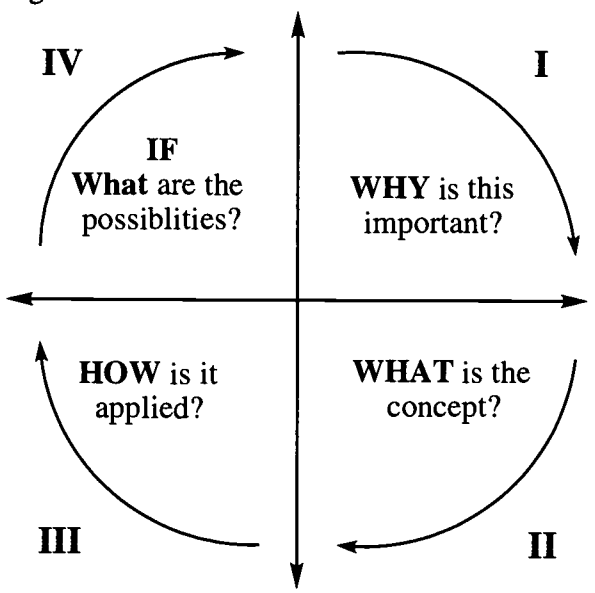


Figure 3.



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